

# Existing Interconnection Requirements: 1547 Interconnection Standards Update



**Inverter Based Generation Power  
System Performance Needs Workshop**

**Co-hosted by PJM, NREL and EPRI**

**Presentation by  
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**April 12, 2012**

# Smart Grid Interconnection & Interoperability Standards Development

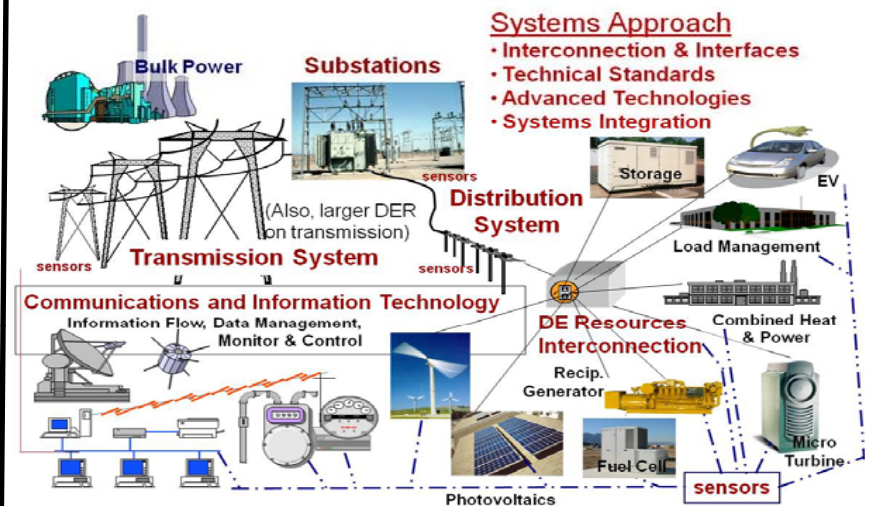
(NREL Work funded by U.S. DOE)

## Objective

To facilitate the evolution of the existing electric power system into a smart grid by supporting the development of standards and best practices.

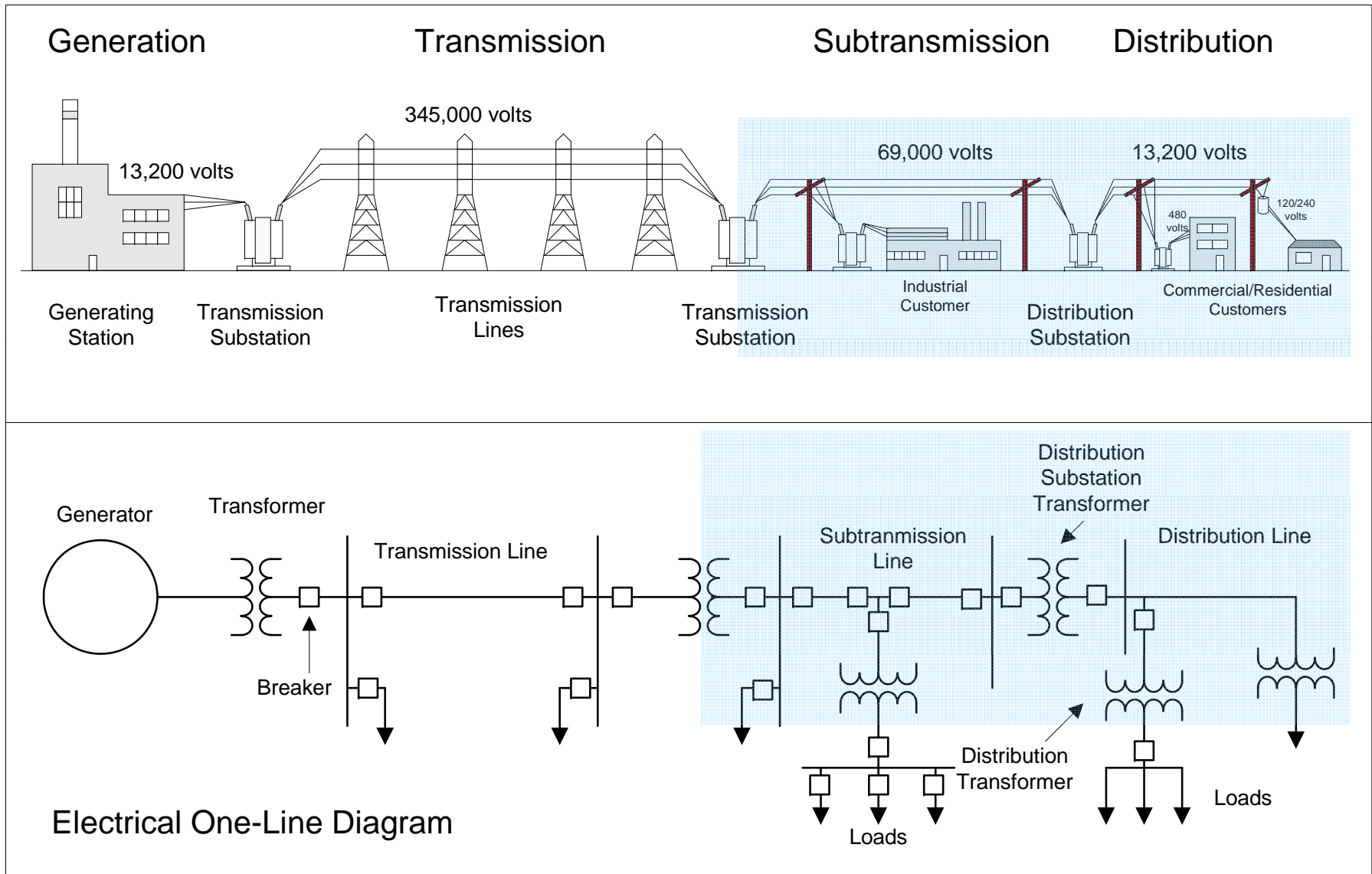
## Technical Scope

Development of national and international standards and best practices for electric power system interfaces, interconnection and interoperability requirements



For background/status visit [www.nrel.gov](http://www.nrel.gov) NREL-CP-5500-53028; *IEEE Smart Grid Series of Standards IEEE 2030 (Interoperability) and IEEE 1547 (Interconnection) Status*; Basso, T. & DeBlasio, R.; Oct . 2011

# The Electricity Grid



# IEEE 1547 Series Standards

**1547-2003** Standard for Interconnecting Distributed Resources (DR) with Electric Power Systems (EPS) - **Reaffirmed in 2008**

**1547.1-2005** Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems – **Reaffirmed in 2011**

**1547.2-2008** Application Guide for IEEE1547 Standard for Interconnecting Distributed Resources with Electric Power Systems

**1547.3- 2007** Guide for Monitoring, Information Exchange and Control of DR

**1547.4-2011** Guide for Design, Operation, and Integration of Distributed Resources Island Systems with Electric Power Systems *{“Micro-grids”}*

*P1547.5 Draft Guidelines for Interconnection of Electric Power Sources Greater Than 10 MVA to the Power Transmission Grid {Withdrawn December 2011}*

**1547.6 -2011** Recommended Practice for Interconnecting Distributed Resources With Electric Power Systems Distribution Secondary Networks

**P1547.7 Draft** Guide to Conducting Distribution Impact Studies for DR Interconnection

**P1547.8 Draft** Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Std 1547

**IEEE 1547  
IS:**

A Technical Standard – Functional Requirements For

- the interconnection itself
- the interconnection test

Technology neutral, e.g., does not specify particular equipment nor type

A single (whole) document of mandatory, uniform, universal, requirements that apply at the PCC.

Should be sufficient for most installations.

**IEEE 1547  
Is NOT:**

- a design handbook
- an application guide
- an interconnection agreement
- prescriptive, e.g., does not address DR self-protection, nor planning, designing, operating, or maintaining the Area EPS.

**IEEE 1547.1 is:**

Test Procedures for  
Conformance to 1547

# IEEE 1547 Interconnection Standards Use:

Federal, Regional, State and Local Authorities/Jurisdictions

## **IEEE 1547** **Interconnection** **System and Test** **Requirements**

- Voltage Regulation
- Grounding
- Disconnects
- Monitoring
- Islanding
- etc.

## **IEEE 1547.1** **Interconnection** **System Testing**

- O/U Voltage and Frequency
- Synchronization
- EMI
- Surge Withstand
- DC injection
- Harmonics
- Islanding
- Reconnection

## **UL 1741\*** **Interconnection** **Equipment**

- 1547.1 Tests
- Construction
- Protection against risks of injury to persons
- Rating, Marking
- Specific DR Tests for various technologies

## **NEC**

Article 690 PV Systems;

Article 705: interconnection systems (shall be suitable per intended use per UL1741)

**PJM Interconnection, Inc.**  
***Small Generator***  
***Interconnection Standards***  
**FERC approved**  
*(0-to<10MW and 10-to-20 MW;  
incorporate 1547 and 1547.1)*

\* UL 1741 supplements and is to be used in conjunction with 1547 and 1547.1

# P1547.7 Guide to Conducting Distribution Impact Studies

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- Describes criteria, scope, & extent for engineering studies of the impact of DR on distribution system.
- Methodology for performing engineering studies.
- Study scope and extent described as functions of identifiable characteristics of:
  - the distributed resource,
  - the area electric power system, and
  - the interconnection.
- Criteria described for determining the necessity of impact mitigation.
- Guide allows a described methodology for:
  - When impact studies are appropriate,
  - What data is required,
  - How studies are performed, and
  - How the study results are evaluated.

# P1547.8 Recommended Practice ... for Expanded Use of IEEE Std 1547

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- Need for P1547.8 is to address industry driven recommendations and NIST smart grid standards framework recommendations (e.g., NIST priority action plans).
- Example considerations include: voltage ride thru; volt-ampere reactive support; grid support; two-way monitoring, information exchange and control; advanced/interactive grid-DR operations; high-penetration levels and multiple interconnections; interactive inverters; energy storage; electric vehicles; DR (and aggregates) greater than 10 MVA; etc.



# IEEE SCC21 Standards Series Next Actions

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- P2030.2 energy storage systems interoperability: May 1-2, 2012, Washington DC
- IEEE SCC21 1547 Workshop: May 17 – 18, 2012 IEEE HQ, Piscataway NJ
- SCC21 series co-located meetings: Aug 20 week in San Francisco CA.
  - P2030.2 energy storage interoperability (Mon-Tues);
  - P1547.7 impacts (Tues-Wed); and
  - P1547.8 expanded use of 1547 (Thurs-Fri).
- P1547.7 IEEE ballot starts: October 2012
- P1547.8 stretch goal: CY 2012 complete document.

# IEEE SCC21 1547 Workshop: May 17-18, 2012

(8 am -8:30 am sign-in; Meet Thurs. 8:30 am - 5 pm and Friday 8:30 am – Noon)

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- **Location:** IEEE HQ, 445 Hoes Lane; Piscataway, NJ 08854
- **Registration required (no later than May 3):**  
<https://web.memberclicks.com/mc/quickForm/viewForm.do?orgId=iecs&formId=115634>
- **Registration fee:** \$150 before 26 April 2012 and \$200 after this date.
- **IEEE 1547 Workshop Technical Ideas Submittal:**  
**Deadline: May 7, 2012**  
you must use the Technical Idea Submittal Form at  
<http://www.surveymonkey.com/s/STD1547>
- **More information is at:**  
<http://grouper.ieee.org/groups/scc21/1547.8/email/>

# THANK YOU!

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{ Additional Background Slides Follow }

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NREL (National Renewable Energy Laboratory)

Distributed Energy Systems Integration Group

Electricity, Resources and Building Systems Integration Center

NREL <http://www.nrel.gov>

Tom Basso: Vice Chair for IEEE Standards Coordinating Committee 21 (SCC21)

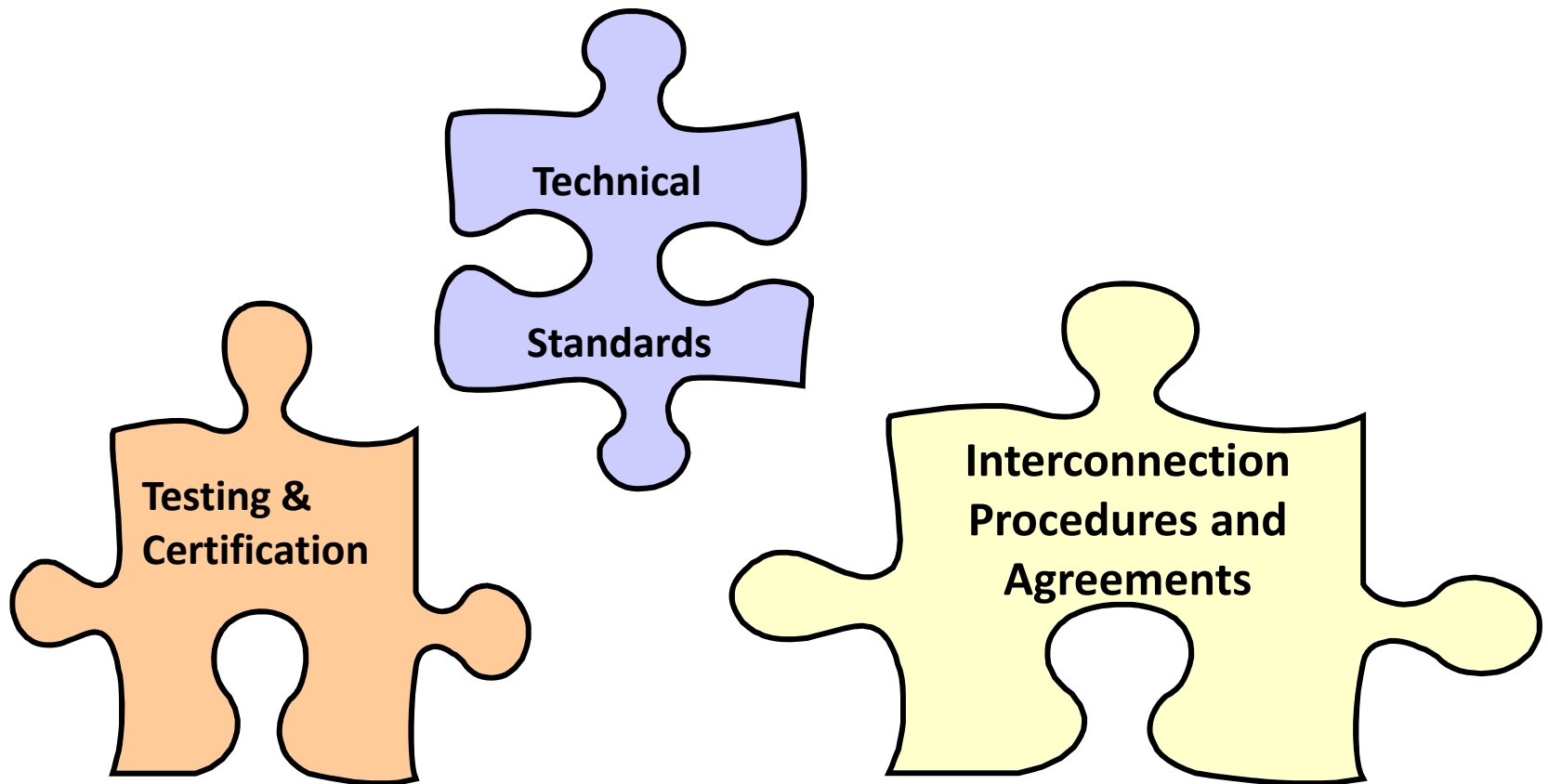
**SCC21: *Fuel Cells, Photovoltaics, Dispersed Generation, & Energy Storage***

<http://grouper.ieee.org/groups/scc21/>

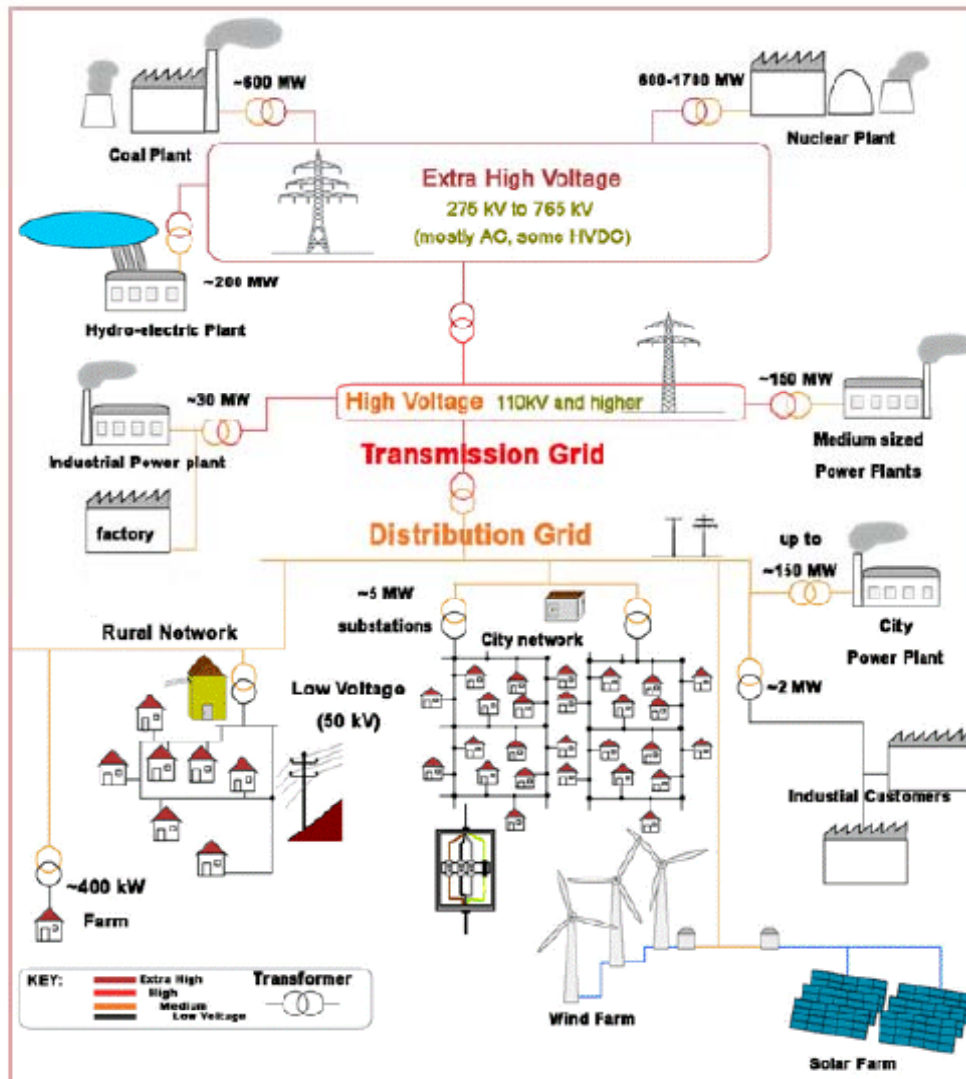
- **IEEE 1547 series** of Smart Grid Interconnection and
- **IEEE 2030 series** of Smart Grid interoperability standards and
- **IEEE PV standards,**

# Interconnection Implementation Challenge: *Putting the Pieces Together*

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# Interconnection Standards, Rules, and Jurisdiction



Bulk System Guidelines  
NERC, FERC  
IEEE, ANSI, IEC  
NESC

Plenty of technical and  
jurisdictional overlap,  
confusion, contradiction...

Distribution System Guidelines  
IEEE 1547, PUC/PRC  
IEEE, ANSI, IEC  
NEC

# ANSI/IEEE Standard 1547 (2003, reaffirmed 2008)

1547™-2003

**IEEE Standards**


## 1547™

### IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems

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Standards Coordinating Committee 21

Sponsored by the  
Standards Coordinating Committee 21 on  
Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage

 **IEEE**

Published by  
The Institute of Electrical and Electronics Engineers, Inc.  
3 Park Avenue, New York, NY 10016-5997, USA

28 July 2003

Print: SH95144  
PDF: SS95144

## 1-2-3 Overview, Definitions, References

### 4.0 Interconnection Technical Specifications and Requirements:

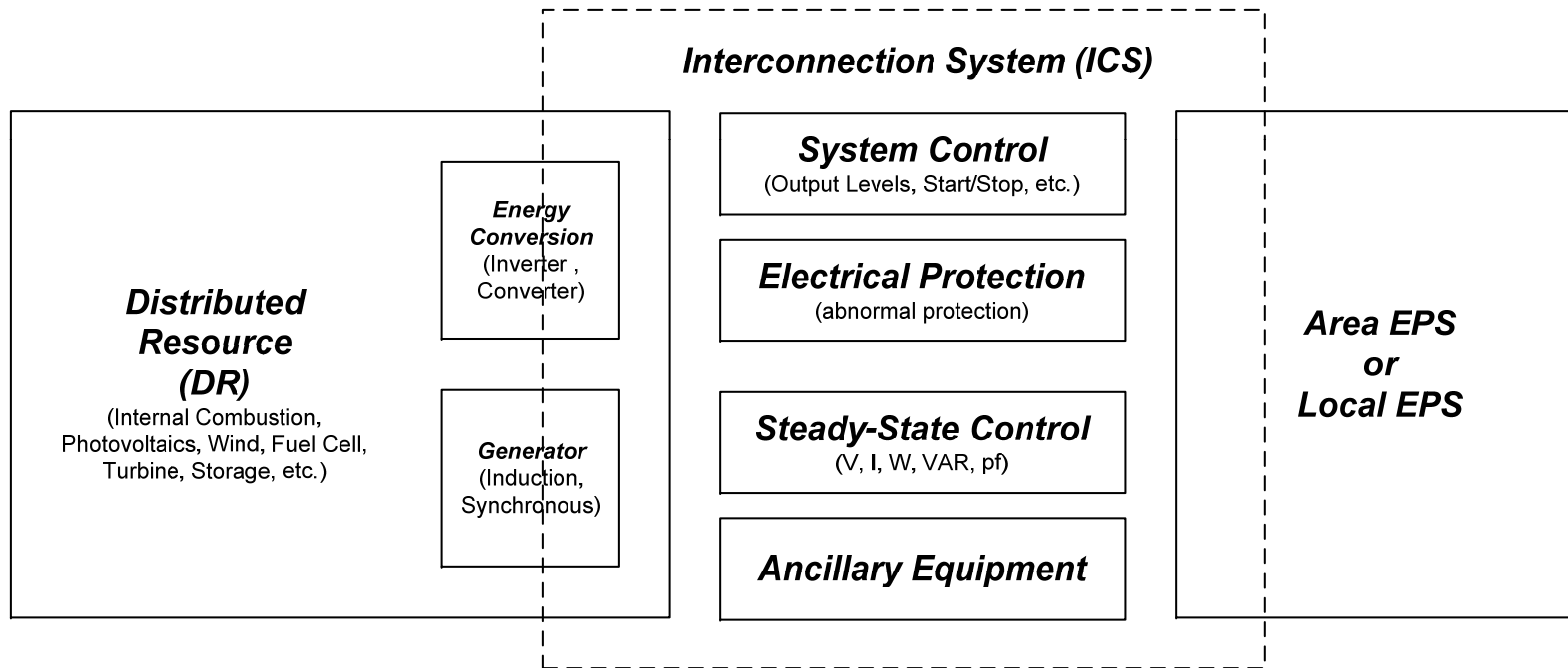
- . General Requirements
- . Response to Area EPS Abnormal Conditions
- . Power Quality
- . Islanding

### 5.0 Test Specifications and Requirements:

- . Design Tests
- . Production Tests
- . Interconnection Installation Evaluation
- . Commissioning Tests
- . Periodic Interconnection Tests

# IEEE Std 1547.1 (2005; reaffirmed 2011)

... *Standard for Conformance Test Procedures* ... specifies the type, production, and commissioning tests that shall be performed to demonstrate that interconnection functions and equipment of a distributed resource (DR) conform to IEEE Std 1547.



1547.1 Figure 1 - Boundaries between the interconnection system, EPS and DR.

# IEEE Std 1547.2 (application guide to IEEE 1547)

... background and rationale of {IEEE 1547} technical requirements are discussed... Presented ... are technical descriptions, schematics, applications guidance, and interconnection examples to enhance the use of IEEE 1547...

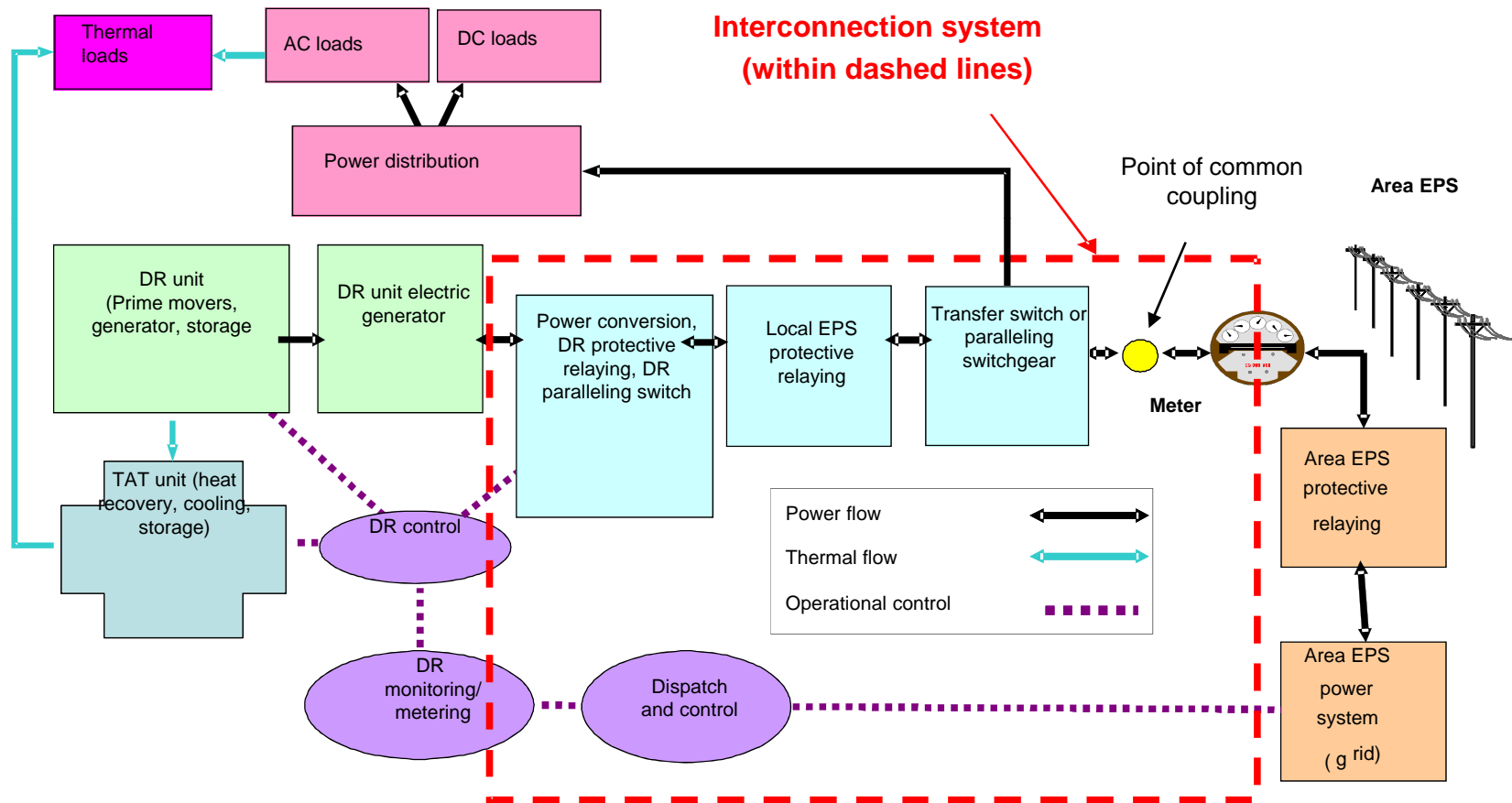


Figure A.1 – Functional diagram of an interconnection system



# IEEE Std 1547.3 MIC for DR

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... guidelines for MIC (monitoring, information exchange, and control) for DR (distributed resources) interconnected with electric power systems (EPS).

...

## 4. General information about monitoring, information exchange and control (MIC)

4.1 Interoperability

4.2 Performance

4.3 Open Systems Approach

4.4 Extensibility

4.5 Automatic Configuration Management

4.6 Information Modeling

4.7 Protocols

5. Data exchange guidelines based on 4.1.6 of IEEE Std 1547

6. Business and operation processes

7. Information exchange model

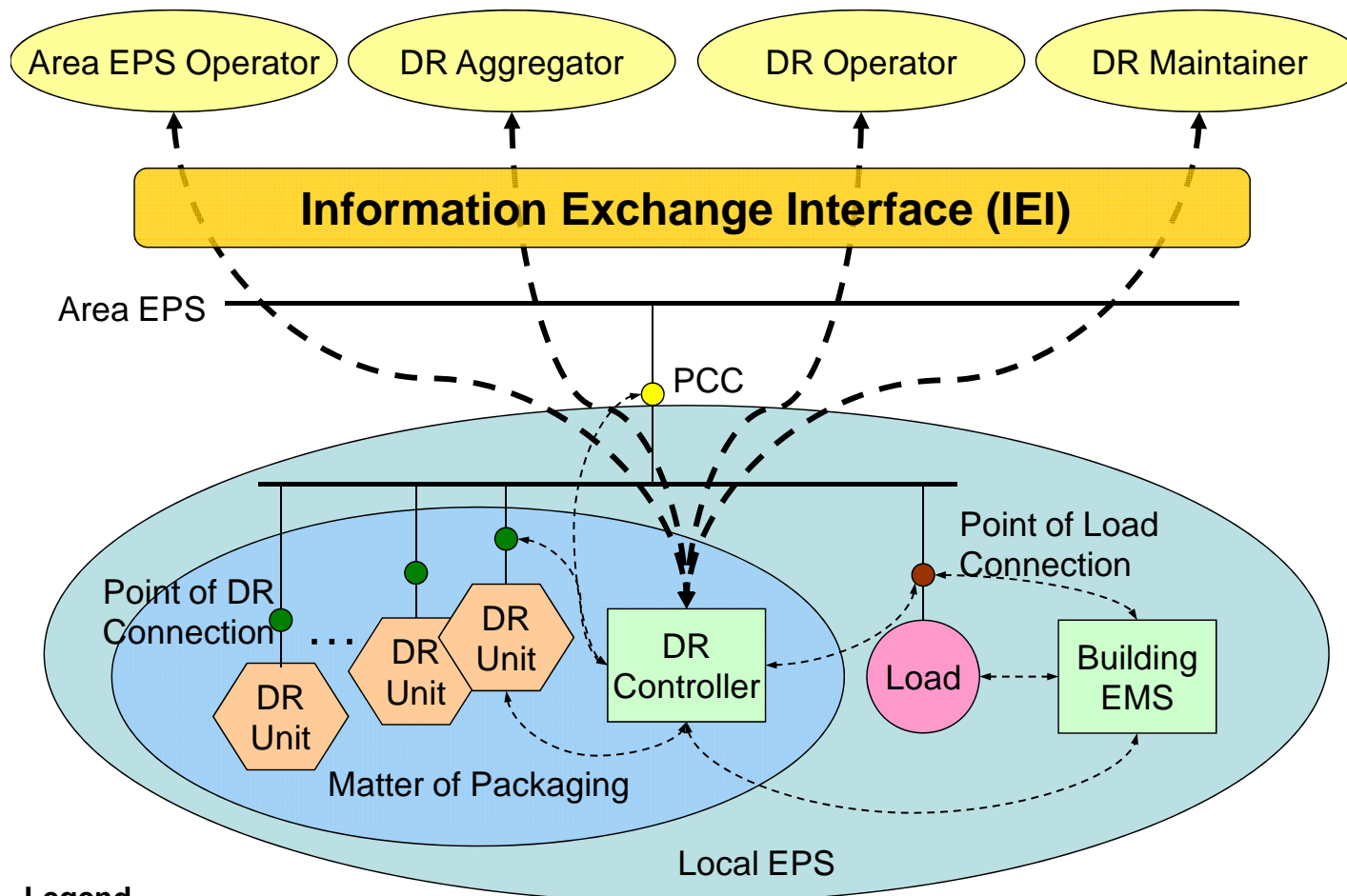
8. Protocol Issues

9. Security guidelines for DR implementation

Annexes (informative)

# IEEE Std 1547.3 Guide for MIC for DR

... guidelines for monitoring, information exchange, and control (MIC) for distributed resources (DR) interconnected with electric power systems (EPS).



**1547.3 Figure 1**  
Reference diagram for information exchange.

## Legend

- Interconnection Info Path (focus of this guide) - - - - -
- Local Info Path (not addressed in this guide) ·····
- Electric Path (not addressed in this guide) \_\_\_\_\_

# IEEE Std 1547.4 (micro-grids/planned DER Islands)

E.g., DER (generation and energy storage) technologies are integrated with all others including the grid technologies to form **Micro-grids (planned islands;** includes – load management, voltage & VAR control, active participation, etc.)

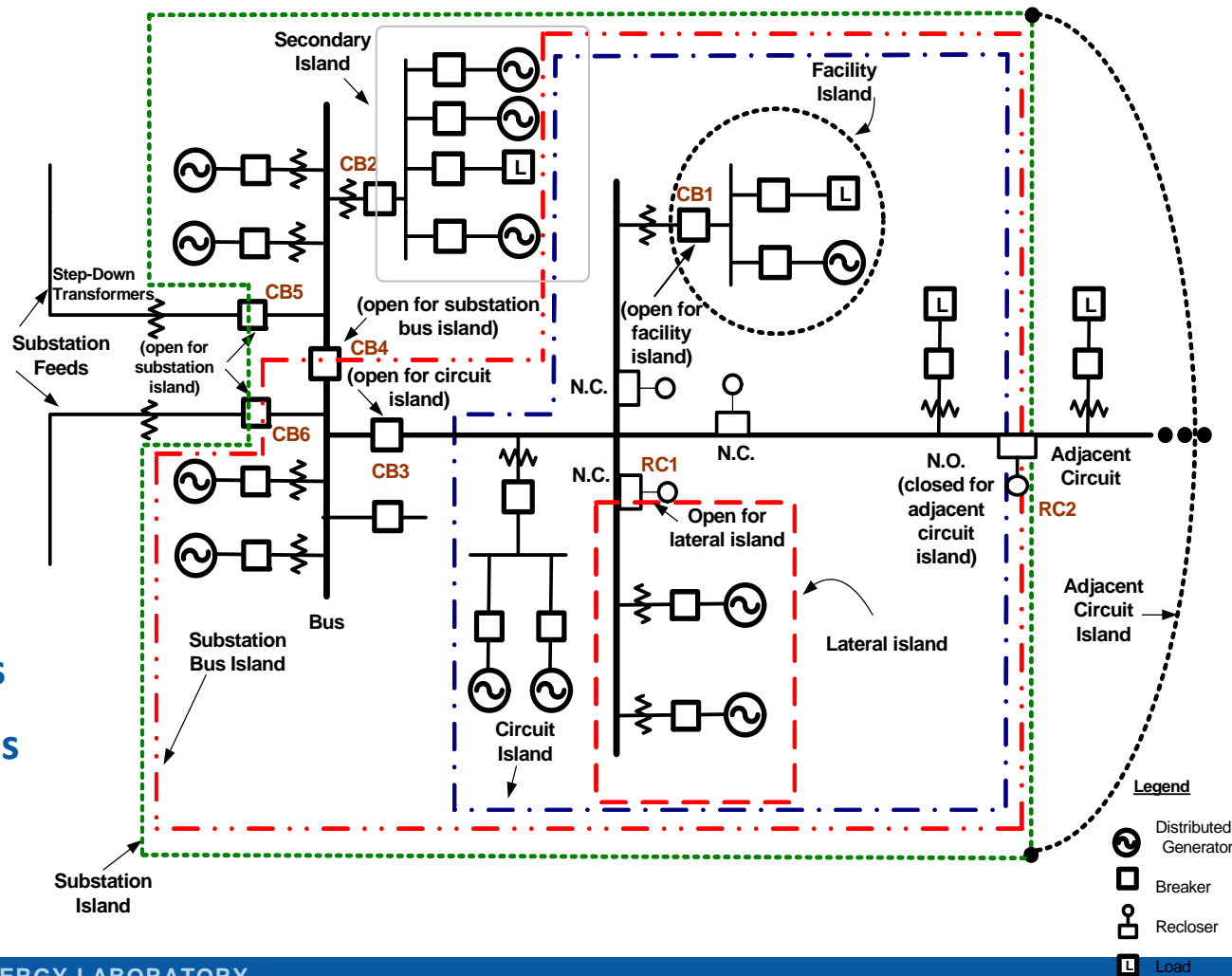


Figure 1 – Examples of DR island systems

# IEEE 1547 Table of Contents

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## INTRODUCTION

### 1.0 OVERVIEW

1.1 Scope

1.2 Purpose – Uniform standard requirements

1.3 Limitations – 10 MVA or less

### 2.0 REFERENCES

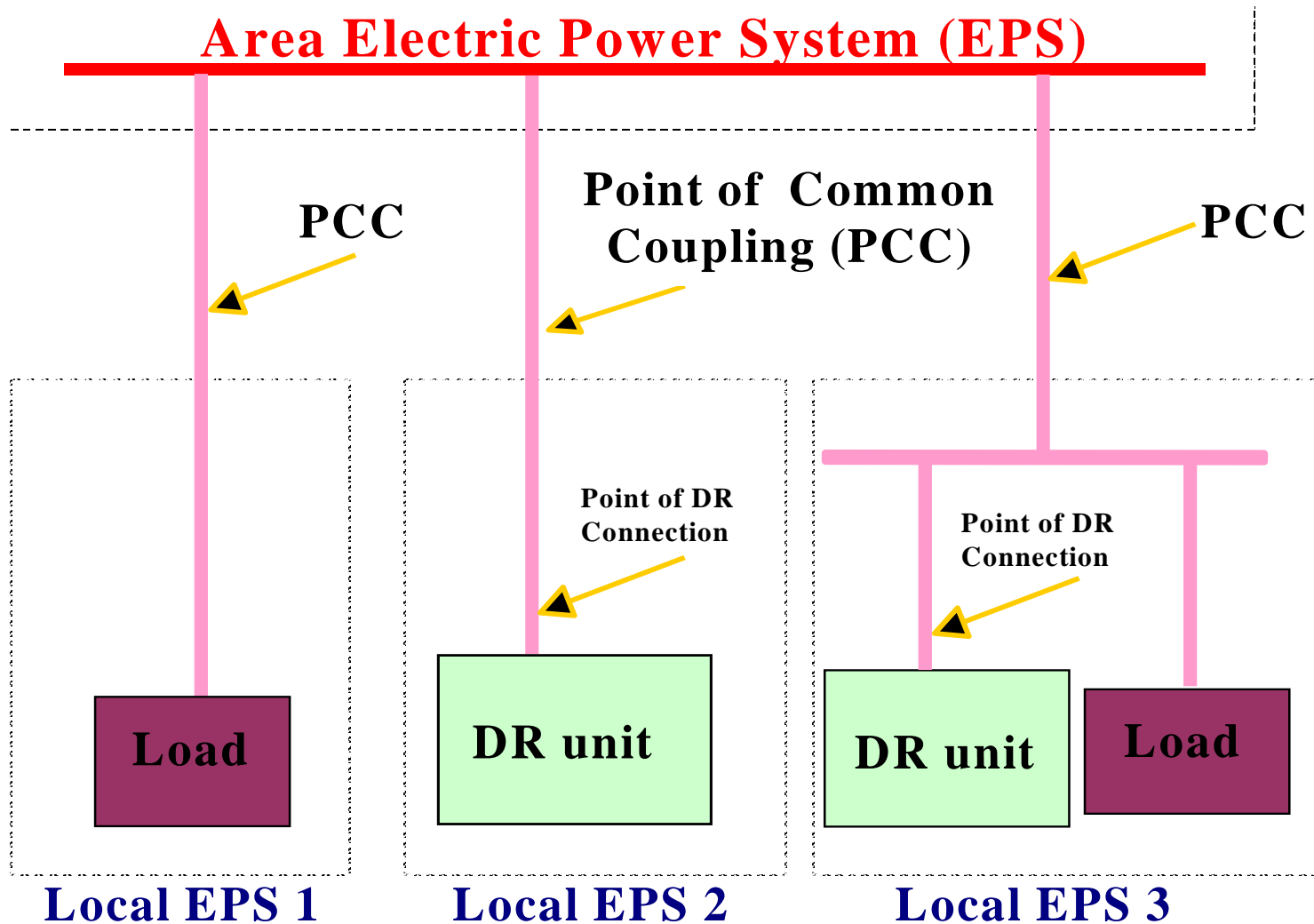
### 3.0 DEFINITIONS

# IEEE 1547 Definitions

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- Distributed Resource (DR) – sources of electric power that are not directly connected to a bulk power transmission system
- Electric Power System (EPS) – facilities that deliver power to a load
- Interconnection – the result of the process of adding a DR unit to an area EPS
- Interconnection Equipment – individual or multiple devices used in an interconnection system
- Interconnection System – the collection of all interconnection equipment, taken as a group, used to interconnect a DR unit(s) to an area EPS
- point of common coupling (PCC) - the point where a Local EPS is connected to an Area EPS.

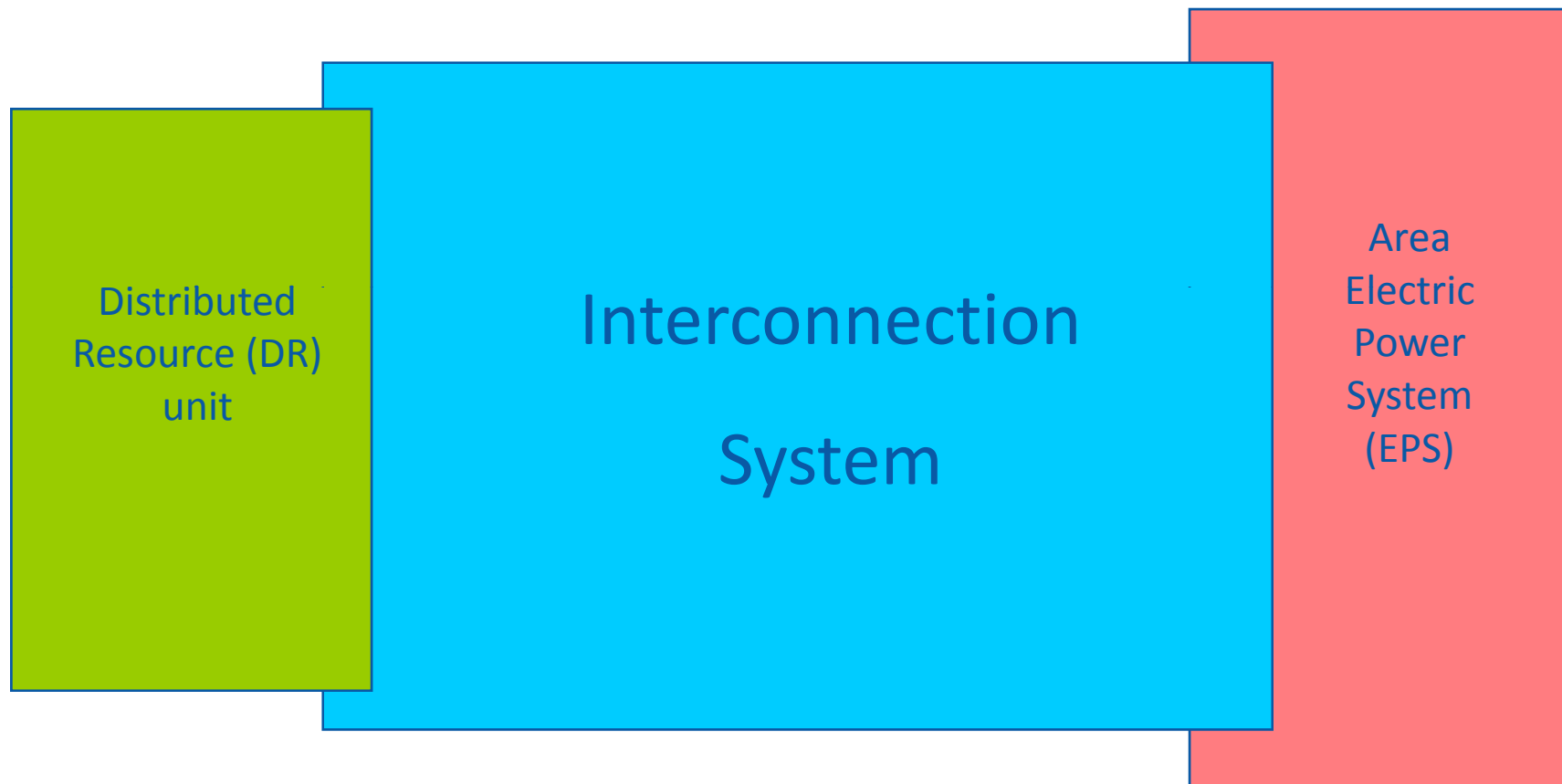
# 1547 Interconnection Terms



**Note: There can be any number of Local EPSs.**

# Std 1547: Interconnection Is The Focus

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**IEEE Std 1547:** Interconnection system requirements & specifications, and test requirements & specifications ; generally, the 1547 requirements apply at the point of common coupling however the equipment or devices to meet the requirements may be located elsewhere.

# IEEE Std 1547

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## 4.0 INTERCONNECTION TECHNICAL SPECIFICATIONS AND REQUIREMENTS

- 4.1 General Requirements
- 4.2 Response to Area EPS Abnormal Conditions
- 4.3 Power Quality
- 4.4 Islanding

## 5.0 INTERCONNECTION TEST SPECIFICATIONS AND REQUIREMENTS

- 5.1 Design Test
  - 5.2 Production Tests
  - 5.3 Interconnection Installation Evaluation
  - 5.4 Commissioning Tests
  - 5.5 Periodic Interconnection Tests
- ANNEX A (INFORMATIVE) BIBLIOGRAPHY



# 4.0 Interconnection Technical Specifications and Requirements

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## 4.1 General Requirements

- Voltage Regulation
- Integration with Area EPS Grounding
- Synchronization
- DR on Secondary Grid and Spot Networks

- Inadvertent Energizing of the Area EPS
- Monitoring Provisions
- Isolation Device
- Interconnect Integrity

### 4.2 Response to Area EPS Abnormal Conditions

- Area EPS Faults
- Area EPS Reclosing Coordination
- Voltage

- Frequency
- Loss of Synchronism
- Reconnection to Area EPS

### 4.3 Power Quality

- Limitation of DC Injection
- Limitation of Voltage Flicker Induced by the DR
- Harmonics

### 4.4 Islanding

- Unintentional Islanding
- Intentional Islanding

# 5.0 INTERCONNECTION TEST SPECIFICATIONS AND REQUIREMENTS

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## 5.1 Design Test

- Abnormal voltage and frequency
- Synchronization
- Interconnection integrity
- Unintentional islanding
- Limitation of DC injection
- Harmonics

## 5.0 INTERCONNECTION TEST SPECS AND REQS (cont'd)

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### 5.2 Production Tests

Meet requirements of:

- response to abnormal voltage and frequency
- synchronization
- may be performed at the factory or at time of commissioning

### 5.3 Interconnection Installation Evaluation

- Grounding Integration with area EPS
- Isolation Device
- Monitoring provisions
- Area EPS faults
- Area EPS reclosing coordination

### 5.4 Commissioning Tests

- Visual Inspection
- Operability test on the isolation device
- Unintentional islanding functionality test
- Cease to energize functionality test

### 5.5 Periodic Interconnection Tests

- All interconnection-related protective functions and associated batteries

## Annex A. Bibliography